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IX. — DIFFRACTION OF SOUND.

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The following experiments were made in order to test the possibility of applying to our atmosphere the principles of Fresnel and Huyghens, which, in their application to the ether, have been attended with such fruitful results.

There seems to be no *a priori* reason why the particles of air, forming, as they do, a medium which, so far as the transmission of wave motion is concerned, is essentially similar to the ether, should not be so acted upon as to produce the interferences known in optical science as diffraction fringes. The following experiments bear upon this point.

The apparatus was so arranged, in the first course of experiments, as to give the best conditions for the study of external fringes, or those produced outside of the geometric shadow of a sharp edge, on which sound waves, diverging from a centre, were allowed to fall.

In the second course, similar waves were made to impinge upon an isolated narrow obstacle, and so to give rise to a system of interior fringes.

All other phenomena of diffraction may be classed as particular cases of one or the other of these two kinds.

First series. A board one hundred and fifty centimetres wide was placed at right angles to, and in contact with, the side of the hall. One hundred and fifty centimetres from the edge, in a line at right angles to the plane of the board, was placed a B_4 stopped lead organ pipe. On the other side of the board, a system of co-ordinates was established by means of light wooden rods, running parallel and perpendicular to the board; these rods being divided into centimetres, it became very easy to locate the points of interference by referring them to these co-ordinates, and so to trace out the bands of interference.

In order to distinguish these bands, I first tried applying my ear to different points along one of the rods; but they were not sufficiently well marked to make them apparent to the unaided ear. I then arranged a resonator, of proper size to resound to the pipe, to slide along the rod; connecting this, by a piece of firm rubber tubing, with the canal of my ear. The other ear I filled first with cotton, and then with putty; so that it was entirely deaf to all sounds. I was thus enabled to annul the effect of every sound but that which was re-enforced by the resonator. Moving now the resonator along the rod, I was able distinctly to mark points of maximum and of minimum intensity, which, in general, coincided with the positions which these bands should occupy as calculated by formulæ essentially similar to those applied in the diffraction of light.

In the first experiments, a number of quite serious difficulties were encountered. Perhaps the most important was that due to the fatigue of the sense of hearing, in consequence of which a maximum was estimated before it actually occurred. By alternately opening and closing the mouth of the resonator with the finger many times in quick succession, however, and by taking a reading by first moving the resonator in one direction, and another by moving it in the other, it became possible to set it with considerable accuracy, the differences being, generally, only a few centimetres. Another difficulty was met with in the shape of a distinct band of interference, seeming to have no connection whatever with the other bands, and following quite a different law. Upon tracing it out, however, it was found to be due to an interference of the direct wave with the wave reflected from the gas-holder used to blow the pipe. Upon covering the holder with a cloth, this was very much diminished: and, upon removing the holder, the interference band disappeared altogether. There seemed to be slight evidences of nodes and loops formed in the hall, as in an organ pipe; these, however, were very indistinct indeed, and were probably not a source of error. An attempt was made to use the manometric flame and revolving mirror to determine the points of most complete interference, but the difference in effect upon the flame was so slight as to render this method entirely impracticable.

In fact, the phenomena of diffraction can be studied only by the closest attention with the ear, and the ear is certainly far more delicate than any instrument of this kind that has ever been constructed. A very pure note, and one of constant intensity was necessary for the best results, and these were obtained by blowing the pipe with a stream of air from a gas-holder, having an arrangement for keeping the pressure constant.

Second series. The same board was set up near the middle of the hall. Two hundred centimetres from its middle point, on one side, was placed the pipe used in the preceding experiments. On the other side was arranged a system of co-ordinates within the sound shadow. The method of determining the points of interference was the same as in the first series; excepting that only the bands of minimum intensity were noted. The whole phenomenon was less distinctly marked than in the case of a single edge; and the bands of maximum intensity were not definitely recognizable. It was only with careful attention that even the bands of minimum intensity could be discovered.

Below are given tables showing the observed and theoretical coordinates of the points of interference noted. Table I. is the case of diffraction from a single edge, and Table II. from a narrow obstacle.

In Table I., the first column gives the distances from the edge of the board measured perpendicularly to its plane: the second and third columns give the observed and calculated abscissas corresponding to these ordinates, for the points of maximum intensity noted; and the fourth and fifth columns the corresponding values for the points of minimum intensity.

In Table II., the first column gives the distances from the middle of the board; the second and third, the observed and theoretical ordinates of the first curve of minimum intensity; and the fourth and fifth columns, the ordinates of the second curve, — all to the right of the middle line; the sixth, seventh, eighth, and ninth give corresponding values for the two curves to the left of the middle line.

TABLE I.

Distances.	Curve of Max. Intens.		Curve of Min. Intens.	
	Obs.	Theor.	Obs.	Theor.
cm.	cm.	cm.	cm.	cm.
100	94	88	129	148
150	120	115	196	200
200	142	144	235	250

TABLE II.

Distances.	Obs.	Theor.	Obs.	Theor.	Obs.	Theor.	Obs.	Theor.
cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.
100	18	19	52	59	17	19	49	59
150	22	25	68	74	21	24	69	74
200	24	30	80	87	24	28	75	89

The theoretical values in the above tables were obtained by a graphical solution, as the formulæ, after undergoing the changes necessarily made, because of the sound waves being of considerable magnitude, became quite cumbersome, and extreme accuracy was not required. The value of λ was carefully determined and properly corrected for temperature.

It should be remarked that all of the above experiments were made in the large hall of the Institute, a room 92′ by 65′.

The phenomena of the diffraction of sound are not so distinctly marked as those of the diffraction of light. An examination of the tables, which are the results of a most careful series of observations, show that we are not warranted in accepting them as a basis for such excellent further work as has been done in the case of light. It is quite possible, of course, to calculate, from the positions of the fringes, the values of λ and therefore of V; to determine the temperature of the room in which the experiments are carried on; or, given these quantities, to deduce the values of physical quantities which are intimately connected with the propagation of sound, and to determine acoustic quantities analogous to those similarly deduced in physical optics: but the method is difficult, uncertain, requires the use of a large hall, physical annoyance to the observer, and, above all, is not susceptible of the desired degree of accuracy.

Their chief value seems to lie in their reactive effect on physical optics. In acoustics we are *sensibly* aware that we are dealing with waves propagated in an elastic medium. These waves may be felt and even seen.* Finding similar effects in optics to those here observed, we immediately refer these similar effects to similar causes, and so place our explanations of the diffraction of light and of the various cases of ethereal interference on a much firmer basis. The experiments show, too, that the principles of Fresnel and Huyghens, announced for the ether, are also applicable to our atmosphere.

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* Expts. of Topfer. Pogg. Ann. 1867.